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# U. S. DEPARTMENT OF AGRICULTURE

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## ORCHARD IRRIGATION



**T**HE PRODUCTION of fruits and nuts on irrigated land has become an important part of the agriculture of the Western States. The favorable climate of the Pacific slope and that portion of the Rocky Mountain States lying in the drainage basin of the Pacific makes those regions well adapted to fruit growing, hence considerable areas are there devoted to orchards. This bulletin is based largely on the practice developed in the sections named.

The first cost of a reliable water supply forms a necessary part of the orchard investment, and the annual costs of maintaining a water system and applying water add to the yearly charges of operation. Moreover, the profits from an irrigated orchard are dependent upon a uniform distribution of water over the surface and a proper control of the soil moisture within the root zone of the trees. Many failures are directly traceable to the insufficiency of the water supply or the manner in which it is controlled and distributed.

This bulletin is a revision of and supersedes Farmers' Bulletin 882, entitled "Irrigation of Orchards."

# ORCHARD IRRIGATION

By **SAMUEL FORTIER**, *Senior Irrigation Engineer, Division of Agricultural Engineering, Bureau of Public Roads*

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## SELECTION OF LOCATIONS

**C**ARE AND GOOD JUDGMENT should be exercised in selecting an orchard tract. If the enterprise turns out well, the profits are high, but if it fails the losses are heavy. Success involves the setting aside of good land, the proper use of irrigation water, and prudence in making the somewhat heavy expenditures required to purchase trees, plant them, and care for them until they begin to bear. The investment is to run a long time and the various factors which are likely to affect the undertaking's success should be considered carefully. Failure may come from causes which are not related to the selection of a site, but the orchardist's chance of success is greatly increased when he takes the precaution to find out the adaptability of the variety of trees he intends to plant to the climate and soil of the locality, the adequacy and dependability of his water supply, the risk of high water table and alkali, the wages of labor and its quality, and the probable cost of packing, inspection, transportation, and marketing of the fruit.

Assuming that the climate and soil of the district selected are adapted to the kind of trees to be grown, the next most important things to seek are good drainage and freedom from unreasonable frosts. Low-lying lands under a new irrigation system should be regarded with suspicion, even if

the subsoil is quite dry at planting time. A few years of heavy and careless irrigation on the adjacent higher lands may render the lowlands unfit for orchards. On the other hand, the higher lands are not always naturally drained. A bank of clay extending across a slope may intercept percolating water and cause it to rise near the surface. Favored locations for orchards in the Mountain States are often found in the narrow river valleys at the mouths of canyons. The coarse soil, steep slopes, and the winds which blow daily in and out of the canyons, afford excellent conditions for the production of highly-flavored fruits at the minimum risk of injury by frost.

Proper exposure is another important factor. In the warmer regions of the West and Southwest a northern exposure sometimes is best; but as a rule the orchards require warmth and sunshine, and usually a southern exposure is most desirable. Natural barriers frequently intercept the sweep of cold, destructive winds, and when these are lacking, windbreaks should be planted to serve the same purpose.

The elevation of the locality likewise should be considered. As a rule, the higher the elevation the colder the climate and the shorter the growing season. It is true also that the low-lying lands of any locality are the most subject to frost. Depressions or sheltered coves should not be selected

for orchards if the cold air has a tendency to collect in them, a free circulation of air being necessary to prevent frost.

The yield and quality of fruit are injuriously affected by abnormal weather conditions. Of these the most common are frosts during the growing season, but heat waves, hail, and high winds also do damage. The occurrence of bad weather can not be predicted far in advance, but some idea of the conditions that may be expected can be gained from a study of the records of the Weather Bureau.

The selection of an orchard site and, more particularly, the kind of trees to plant, may be governed largely by economic factors. In localities where citrus fruits can be grown successfully the cost of land and water may be too high for the profitable production of deciduous fruits. Also, the packing and inspection of fruit, adequacy and cheapness of transportation, and nearness to good markets, greatly affect the profits of the grower.

Experience has shown that orchard trees of nearly all kinds can be grown successfully on soils that differ widely in their physical and chemical composition, and it has also shown that certain types of soils are best adapted to particular kinds of trees. The best peach, almond, apricot, and olive orchards of the West are found on the lighter or sandier loams, and the best apple, walnut, cherry, and pear orchards on heavier loams, whereas prune and citrus orchards do best on medium grades of soil. All, however, thrive best on a soil that is deep, rich, and well drained.

### CLEARING AND GRADING LAND

Orchard trees often are set out before the land surface is graded, provided no brush or trees must be removed. This is not good practice. It is better to anticipate the planting of trees by a few years of preparation. If trees and shrubs have to be removed, the smaller roots should be allowed to decay; and if grading is to be done, the newly made soil should have time to settle before orchard trees are planted. Alfalfa is one of the best preparatory crops for orchards. This vigorous plant breaks up the soil and subsoil. Its roots collect and store valuable plant foods, and when it is turned under at the end of the second or third year it

leaves the soil in much improved condition for the retention of moisture and the growth of young trees.

In Bitterroot Valley, Mont., new land is first plowed 8 to 10 inches deep, then carefully graded and smoothed, and seeded to red clover for one or two seasons. On the west side of this valley, pine trees and pine stumps must be removed. Large areas of wooded lands in both the Hood River and Rogue River Valleys of Oregon have been cleared for orchard plantings. The Oregon Experiment Station has studied the subject of removing stumps from cutover lands,<sup>1</sup> and recently the Division of Agricultural Engineering of the Bureau of Public Roads has made an extensive study of methods of clearing land.

Devices for the removal of ordinary desert plants, such as sagebrush and greasewood, have been described in another bulletin.<sup>2</sup>

In the later plantings of citrus orchards in some sections of southern California, large quantities of boulders and cobbles are hauled from the land and piled in walls around the edges of the tracts. The cost of removing the rocks sometimes exceeds \$100 per acre. Such lands are among the most desirable for citrus fruits, because they are near the foothills and at elevations where there is less frost than in the lower parts of the valleys.

### LOCATING THE TREE ROWS

The location of the trees can be fixed best by the use of a surveyor's light transit and steel tape. When these are not available, a woven-wire cable about three-sixteenths inch in diameter will answer the purpose in all but contour planting. If apple trees are set out and it is desired to have them 32 feet apart, tags are inserted between the strands of the cable to mark this distance. A base line at the proper distance from the fence or one margin of the field is then located, and a long sighting stake is driven at each tag. The next step is to locate a side of the field at right angles to this line. A right angle can best be laid off with

<sup>1</sup> SCUDDER, H. D. STUMP LAND RECLAMATION IN OREGON. *Oreg. Agr. Coll. Agr. Exp. Sta. Bul.* 195, 1922.

<sup>2</sup> FORTIER, SAMUEL. PRACTICAL INFORMATION FOR BEGINNERS IN IRRIGATION. U. S. Dept. of Agr. *Farmers' Bul.* 864. 38 pp. illus. 1917.

a 100-foot tape or link chain, as follows: First, locate a point on the base line 30 feet from the end. Hold the 100-foot end of the chain at this point, and the 10-foot mark at the corner; take the chain at the 50-foot mark and pull both lines taut. A stake driven at this vertex will establish a point on a line at right angles to the base line. This new line is then staked in the same way as the base line, similar methods are employed to locate and stake the opposite end of the field and finally the side opposite the base line is staked. When stakes have been set on all four sides, the intermediate locations for the trees can be ascertained readily by sighting between corresponding marginal stakes.

Where the slope is fairly steep and difficulties are likely to be encountered in distributing water, the "triangular" method possesses some advantages over the square method. This plan is shown in Figure 1. It will be observed that in this method the ground is divided into equilateral triangles, with a tree at each vertex. The trees likewise form hexagons, and including the center tree of each hexagon they form groups of sevens—hence the names equilateral, hexagonal, and septuple. This method provides two or more different directions in which furrows may be run, and, with such a choice, it is not difficult to select the one which is best for any particular slope. The ground likewise can be cultivated in several ways and about one-seventh more trees can be planted to a given area than is permitted by the square method.

In the past the trees of many irrigated orchards have been planted too close. This is made clear even to the casual observer who visits the old orange groves of Riverside, Calif., the deciduous orchards of the Santa Clara Valley, Calif., or the apple orchards of the Hood River district in Oregon.

The spacing of trees is influenced by the use of fillers and the growing of intercroppings and cover crops between the rows. The use of fillers is becoming less common. Many orchardists of the Northwest object to having different varieties of trees on the same tract for the following reasons: The soil requirements may differ, as in the case of peach fillers used in an apple orchard; the quantity of water required and the time of application are likely to differ; one variety of fruit may require frequent spraying or smudge pots, while the other does not; the cost of harvesting is increased by the differences in time of ripening.

Most of these objections are overcome by planting the same variety as fillers. Thus, apple trees may be planted in squares 20 feet apart; then at the age of 15 to 17 years alternate trees are removed, leaving a hexagonal system. Walnut trees may be planted in rows 60 feet apart and 30 feet apart in the row, and at the age of 10 to 14 years alternate trees in each row are removed. An orchard in Orange County, Calif., was recently planted in walnut trees, rows of which alternated with rows of orange trees, with Lima beans as an intercrop.

The spacings of the standard varieties of fruit trees grown under irrigation where no fillers are inserted are about as follows: Figs and walnuts, 48 to 60 feet; apples, 25 to 40 feet; prunes and pears, 24 feet;

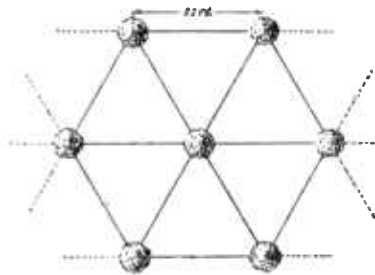


FIG. 1.—Triangular arrangement of trees

peaches, 22 feet; oranges, 22 to 25 feet; and olives, cherries, and apricots, 22 to 28 feet.

### CONTOUR METHOD OF PLANTING TREES

The central plain of California is surrounded by foothills and southern California has foothills on the north and west. High winter temperatures and good air drainage makes these foothill lands, in many localities, desirable for fruit growing. However, they have one drawback—the steepness of the slopes increases the cost of all operations connected with the growing and harvesting of fruit. Experience has shown that it is especially difficult to irrigate orchards planted in squares on steep slopes, because the water in running down erodes the soil and a uniform moistening of the root zone of each tree can not be attained. It was largely to overcome the objectionable features of the common method of irrigating and to insure a proper grade for furrows that contour planting was introduced. Setting out trees in this way costs more and

adds to the labor of cultivating, but these objections are more than counterbalanced by many advantages. The contour method makes available for orchards land too steep for other crops, provides a fairly efficient means of irrigation under difficult conditions, and lessens surface grading and thereby makes available shallower soils. By its use the damage from winter rainstorms is reduced, and it provides a means of utilizing land which is less subject to frost.

There are two more or less distinct types of contour plantings, as outlined in Figures 2 and 3. In Figure 2 the trees are planted in straight rows down the steepest slope, and as nearly



FIG. 2.—Contour planting on fairly uniform grade with straight rows up and down the slope

as practicable on a uniform grade. In Figure 3, the trees are shown planted on a constant grade and with constant spacing along the rows.

When a layout is made with engineering instruments, the first thing to do is to establish a control tree row adjacent to and parallel with the water supply conduit as indicated on the left of Figure 4. Each stake in this row indicates the head of a tree row. A line is then run out from each stake in the control row following a course which will give the tree row a uniform slope, and stakes are set at desired distances to mark the locations of trees. When the cross slope increases enough to cause the distance between rows to become too small, a stub row results and a new row is started from the control. A fill row is shown at the lower right in Figure 4. Should the cross slope decrease near the lower end of a row, causing the rows to diverge, a spike row may be inserted. However, stub, fill, and spike rows should not be introduced if a slight variation in grade or spacing will serve the purpose.

A variation of the above method is to establish a control row as described and locate three lines at right angles to it, one at each end and the other midway between, and set a marker for each tree row down the slope. The exact location of each tree is then found by lining up with these markers

and determining the proper position on the slope with a leveling instrument. The object in either method is to have straight rows running down the slope and rows having a uniform grade running out from the main supply conduit. Any irregularities that may be found in either method can be smoothed out later by moving the stakes short distances.

A slope board may be used instead of engineer's instruments. This is a board of the same length as the tree spacing, with two legs, the difference in the length of which represents the grade. The short leg is placed at a tree location on the control row and the other leg is turned around until it rests on the ground and the bubble of a spirit level on the board is centered, when the tree location is marked. The board is then carried forward, the short leg is placed by the newly set stake, and the operation is repeated.

As a rule, the grades in contour planting vary from 1 foot to 2 feet in 100 feet (1 to 2 per cent), depending on the character of the soil. Theoretically the side slope of the land should not influence the flow of water on a fixed furrow grade; but, in practice, contour plantings on side slopes of 15 to 25 per cent are made with steeper furrow grades than those on side slopes of 5 to 15 per cent, to lessen



FIG. 3.—Contour planting on constant grade with constant spacing

the risk of clogging furrows, which would cause the water to overflow from one contour furrow into the one next lower, and bring about soil erosion if the flow of a large number of furrows should accumulate. For this reason the furrow grades on steep side slopes of 25 per cent are usually nearly 1 per cent more than they are on easy side slopes of 5 per cent.

### COST OF WATER

The regulations governing the delivery of water seldom make any distinction affecting the crops grown on farms within the confines of any one enterprise, except that provision is sometimes made for giving preference to certain crops in times of water

shortage. The farms devoted in whole or in part to the production of fruit are entitled to the same quantity of water per acre at the same rate as farms which have no orchards. Accordingly, the water supply for orchards does not differ in the main from that of any other crop, except in favored localities especially adapted to fruit growing, where the profits are high enough to warrant the installation of costly equipment.

Although the annual cost of water in itself often amounts to a large sum, studies by the Division of Agricultural Engineering indicate that they may not constitute a large proportion of the total expenditure for the operation of an orchard farm. In one of the best-known irrigated sections of the Northwest, where apples constitute the major crop, the rate charged for water per acre is much higher than the average water charge; yet water payments represented only 4 per cent of total farm expenditures for the average farm in 1924 and only 2 per cent of the average farmer's receipts from farm products. Hence, although it is of importance to ascertain what expense is to be involved in water charges, it should also be kept in mind that a profitable orchard can stand an expense for water which might be too heavy for other types of farms.

### MEASUREMENT OF WATER

The units generally used in measuring water for orchards are the cubic foot per second, miner's inch, acre-foot, acre-inch, and gallon. The cubic foot per second, sometimes abbreviated to "second-foot," is the standard unit for flowing water. It is the equivalent of a column of water 1 foot square moving at the rate of 1 foot per second and should be applied to the measurement of all but the smaller flows. The miner's inch is a variable unit, equalling one-fiftieth second-foot in Idaho, Kansas, New Mexico, North Dakota, South Dakota, Nebraska, Utah, and southern California, and one-fortieth second-foot in Arizona, Montana, Oregon, and northern and central California. The United States gallon contains 231 cubic inches and is used to indicate the discharge of pumps and pumping plants in gallons per minute. The acre-foot and its twelfth part, the acre-inch, are used to measure water at rest. The same unit is likewise used to indicate the

quantity of water applied in irrigation through any period of time.

One of the cheapest and most effective devices for measuring flowing water is the weir.<sup>3</sup> A disadvantage of the weir is that it requires considerable fall to operate accurately. This defect is avoided in a somewhat different device known as the improved Venturi flume, developed by the Bureau of Public Roads.<sup>4</sup> It consists of a converging portion with a level floor,

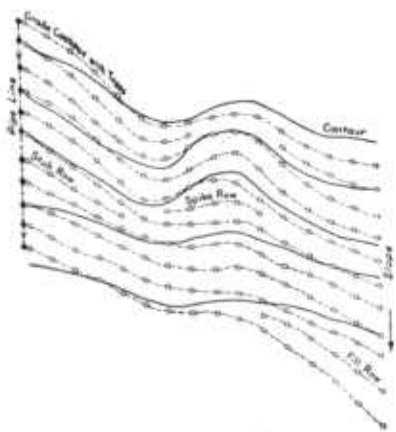


FIG. 4—Contour planting, showing stub, fill, and spike rows. Contour interval, 2 feet; trees 24 feet apart; grade, 6 inches per 100 feet

a throat or contracted section having a floor that slopes downward, a diverging section with floor which slopes upward, and a well to record the height of the water. A flume of this type installed under free flow conditions is shown in Figure 5. This device is accurate enough for practical purposes. It operates successfully under a quarter of the head required by weirs; sand or silt in the water does not affect its operation or accuracy; and it has a wide range of capacities.

Other measuring devices, many of which are particularly adapted to the special needs of different localities, have been widely used in those sections but have not found favor elsewhere. However, the rising cost of water in many sections specializing in fruit growing, and the desirability

<sup>3</sup> CONE, V. M. CONSTRUCTION AND USE OF FARM WEIRS. U. S. Dept. Agr. Farmers' Bul. 813. 19 pp., illus. 1917.

<sup>4</sup> PARSHALL, R. L. THE IMPROVED VENTURI FLUME. Colo. Sta. Press Bul. 60. 1925.

of applying only the proper quantities even when water is plentiful, encourage the installation of accurate measuring devices by orchardists.

### IRRIGATION LAYOUTS FOR ORCHARDS

As a rule the diversification or interplanting of orchards with other crops is practiced where failures of fruit crops are common or where profitable returns can not be depended upon. In many areas, however, where this danger does not exist, one of which is the Lower Rio Grande Valley of Texas, fruit growing is combined with the production of other crops which



FIG. 5.—Improved Venturi flume with 1-foot throat and free flow

are profitable because of favorable climate and soil, cheap labor, and access to early markets. A typical Lower Rio Grande Valley farm in early spring is shown in Figure 6. It contains 22½ acres, of which 18 acres are under diversified crops. Only 4½ acres are in citrus trees, but an additional area will be planted as the older trees reach full maturity and swell the profits from the farm. The corn and sorghum are for home use. The cotton, cabbage, corn, and sorghum will be followed later in the year by other crops. The water is carried from the highest corner of the farm in earthen ditches which provide a head ditch for each field. The border and furrow methods of irrigation are used, the length of run for each being indicated.

Part of a deciduous fruit farm near Grandview, Wash., is sketched in Figure 7. The water is conveyed in wooden pipes 4 to 6 inches in diameter from a head gate of a lateral ditch of the system, and small hydrants three-fourths inch to 1 inch in diameter, controlled by valves, are inserted in the pipes at suitable intervals to supply water to the furrows. A part of the drainage system of the country is also shown.

An irrigation layout typical of the citrus groves of southern California has a 10-inch supply line, an underground concrete 8-inch pipe which carries the water along the upper side of the orchard, and a branch line extending down one side to a second head pipe of the same size in the middle of the grove. The flow to the furrows is controlled by means of small stands at the head of the tree rows.

Citrus orchards of the Federal Reclamation project near Yuma, Ariz., are in 10 and 20 acre tracts. The land being nearly level, the head ditch, flume or pipe line usually can be located in the middle of the tract and the water distributed on each side. A typical 20-acre orchard has a centrally located concrete flume 24 inches wide and 12 inches deep, from which water is distributed laterally to the furrows between the tree rows. The slope of the furrows is 1 inch to the 100 feet, or more.

Water for certain apricot and prune orchards near San Jose, Calif., is pumped from a shallow well on the bank of a creek through 1,400 feet of 10-inch concrete pipe. Part of this discharge pipe operates under a head of 80 feet, and this section, about 400 feet in length, consists of double-strength pipe, 2 inches thick. The middle 600 feet of the line is under a head of 35 to 64 feet and the pipe used is 1½ inches thick. On the upper 450 feet the head does not exceed 35 feet, and standard concrete pipe, fifteen-sixteenths inch thick, is used. To overcome water-hammer, a steel air dome was placed near the pump. This consisted of a standard 40-gallon house water tank connected to the discharge pipe and anchored by a block of concrete. The water is distributed from the discharge pipe to the furrows of the orchard on both sides of the line by hydrants.

The water supply for a diversified farm near Brigham City, Utah, is pumped from a well into a concrete flume extending across the upper

boundary of the orchard. The water passes from the flume into earthen ditches which convey it to the several fields, as outlined in Figure 8.

Recently a 300-acre tract in Yuba County, Calif., was subdivided, most of the blocks being 440 feet wide and 660 feet long. The water supply of the subdivided tract is pumped from Feather River through a concrete pipe 20 inches in diameter. The distributary pipe lines are of the same material, range in diameter from 10 to 16 inches, and are fitted with alfalfa hydrants. The entire tract is planted to pears.

### UNDERGROUND PIPE SYSTEMS

Head flumes, since they must be placed on the ground surface, inter-

quoted in January, 1925, by a firm at San Jose, Calif., for units  $2\frac{1}{2}$  feet long.

TABLE 1.—Size, price, and weight of thin-shelled concrete pipe for general orchard use

Size	Price per foot at plant	Price per foot installed	Weight per foot
Inches	Dollars	Dollars	Pounds
8	0.25	0.33	27
10	.30	.40	37.6
12	.38	.50	46.2
14	.48	.63	56.4
16	.65	.88	75.2
18	.82	1.05	98.8

Clay pipe of the form and type used for city-sewer systems is occasionally used to distribute water in orchards

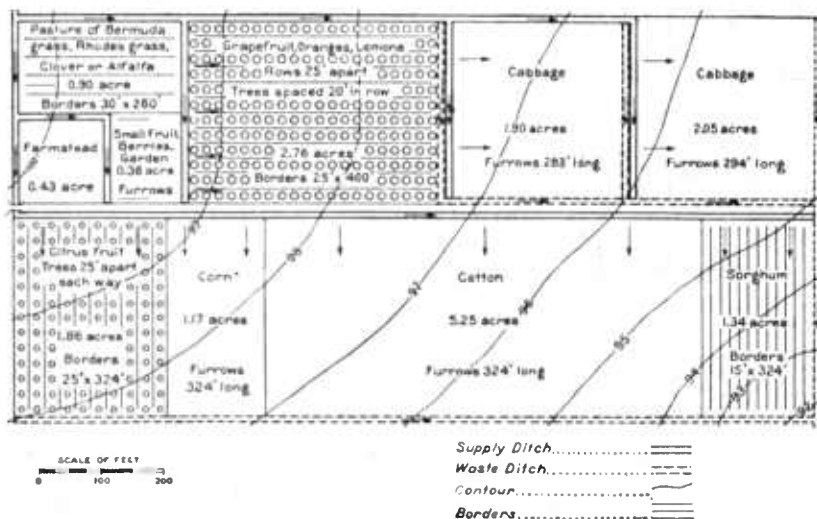


FIG. 6.—Irrigation layout of earth ditches for a 20-acre diversified farm in southern Texas

fare with cultivation, irrigation, and harvesting, and leaves clog their small openings. These objections have induced many fruit growers to convey the water in underground pipes, and distribute it through standpipes, or "stands" as they are more frequently called, at the heads of the tree rows. Several kinds of pipe are used, but concrete is the most common.

Formerly concrete-pipe systems could not be subjected to heads of more than about 15 feet because of the risk of failure of improperly made pipe. At present standard pipe 8 to 14 inches in diameter is laid under heads of 40 feet. The size, price, and weight of thin-shelled concrete pipe applicable to general orchard use are given in Table 1. The prices were

under low heads. The weight, dimensions, and price of standard strength clay pipe, as quoted January, 1925, by a California firm, appear in Table 2.

TABLE 2.—Weight, dimensions, and price of standard strength clay pipe

Inside diameter	Weight per foot	Length	Thickness	Depth socket	Annular space	Area	Price per foot
In.	Lbs.	Ft.	In.	In.	In.	Sq. ins.	Dolls.
3	6	2	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	7	0.12
4	8	2	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	12 $\frac{1}{2}$	.15
5	12	2	$\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{4}$	19 $\frac{1}{2}$	.18
6	16	2	$\frac{3}{8}$	2	$\frac{1}{4}$	28 $\frac{1}{2}$	.21
8	22	2 $\frac{1}{2}$	$\frac{3}{8}$	2 $\frac{1}{4}$	$\frac{1}{4}$	50 $\frac{1}{2}$	.30
10	31	2 $\frac{1}{2}$	$\frac{7}{8}$	2 $\frac{1}{2}$	$\frac{1}{4}$	78 $\frac{1}{2}$	.42
12	41	2 $\frac{1}{2}$	1	2 $\frac{1}{2}$	$\frac{1}{2}$	113	.54

Where pressure is high, riveted-steel pipe with slip joints may be used either to convey water to an orchard or to distribute it. The price (January 1, 1925), weight, and safe head in feet for three thicknesses of steel as made by a firm in Los Angeles, Calif., are shown in Table 3.

TABLE 3.—*Price, weight, and safe head of steel pipes*

NO. 16 GAUGE			
Diam-eter	Price per foot	Weight per foot	Safe head
Inches	Dollars	Pounds	Feet
4	0.29	3.7	390
5	.34	4.4	360
6	.41	5.3	340
7	.45	6.2	325
8	.50	7.0	315
9	.55	7.8	290
10	.61	8.6	252
12	.71	10.3	210

NO. 14 GAUGE			
Diam-eter	Price per foot	Weight per foot	Safe head
Inches	Dollars	Pounds	Feet
4	0.34	4.4	480
5	.40	5.4	450
6	.49	6.4	430
7	.53	7.4	410
8	.59	8.4	394
9	.65	9.4	350
10	.74	10.4	316
12	.85	12.4	263

TABLE 3.—*Price, weight, and safe head of steel pipes—Continued*

NO. 12 GAUGE			
Diam-eter	Price per foot	Weight per foot	Safe head
Inches	Dollars	Pounds	Feet
8	0.80	11.6	553
9	.87	12.9	490
10	1.00	14.3	443
12	1.17	16.9	368

In many orchards in Washington and Oregon, and to a less extent in other Western States, wooden pipe is used both to convey and to distribute water. Such pipe is generally made of continuous staves, and ranges from 1 to 12 feet in diameter. The pipe used to distribute water in orchards are machine-banded with spiral steel hoops, and range in diameter from 2 to 12 inches or more. Wooden pipe may be creosoted at a cost of 4 to 20 cents per foot, depending on the size, and this process greatly prolongs its life.

The size, safe head, kind of joint, and price (January 1, 1925) of wood-stave pipe, as made by a firm in Seattle, Wash. are given in Table 4.

TABLE 4.—*Size, safe head, kind of joint, and price of wood-stave pipe*

Diam-eter of pipe	Safe head	Kind of joint	Weight per 100 feet	Price per 100 feet untreated and coated	Add per 100 feet for creosoted pipe	
					Uncoated	Coated
Inches	Feet		Pounds	Dollars	Dollars	Dollars
2	50	Inserted joint .....	327	20	3	4
	100	do. ....	337	21	3	4
	250	do. ....	376	24	3	4
3	50	do. ....	426	25	4	5
	100	do. ....	440	26	4	5
	250	6-inch wire-wound collar <sup>1</sup> .....	497	33	4	5
4	50	Inserted joint .....	563	31	6	8
	100	do. ....	579	32	6	8
	250	6-inch wire-wound collar .....	646	36	6	8
5	50	Inserted joint .....	668	36	7	9
	100	do. ....	687	38	7	9
	250	6-inch wire-wound collar <sup>2</sup> .....	774	48	7	9
6	50	Inserted joint .....	852	44	8	10
	100	do. ....	870	46	8	10
	250	6-inch wire-wound collar .....	990	57	8	10
8	50	Inserted joint .....	1,081	55	10	13
	100	do. ....	1,119	58	10	13
	250	6-inch wire-wound collar <sup>3</sup> .....	1,305	74	10	13
10	50	Inserted joint .....	1,367	69	13	16
	100	do. ....	1,430	74	13	16
	250	6-inch wire-wound collar <sup>4</sup> .....	1,675	95	13	16
12	50	Inserted joint .....	1,680	79	16	20
	100	do. ....	1,769	85	16	20
	250	8-inch wire-wound collar <sup>5</sup> .....	2,155	117	16	20

<sup>1</sup> Add to the above prices for collars instead of inserted joint, where specified, per 100 feet, \$2.

<sup>2</sup> Add to the above prices for collars instead of inserted joint, where specified, per 100 feet, \$3.

<sup>3</sup> Add to the above prices for collars instead of inserted joint, where specified, per 100 feet, \$4.

<sup>4</sup> Add to the above prices for collars instead of inserted joint, where specified, per 100 feet, \$5.

<sup>5</sup> Add to the above prices for collars instead of inserted joint, where specified, per 100 feet, \$6.

It is essential to plan pipe systems for orchards on contour surveys, and to base the location and spacing of the trees on the pipe system. Success depends largely on the skill exercised in adjusting both trees and pipes to the topography, soil, and water supply of the tract. The sizes of pipe needed<sup>5</sup> will depend on the area, the grades of the pipe lines, the interior smoothness of the pipe and its joints, and the water requirement of the trees.

but when they are closed the full head, with any water hammer that may occur, acts on the pipe. To prevent higher pressures than the pipe can safely resist, standpipes are inserted. These are of various heights and types, but all serve to limit pressure and bypass excess water after it has reached a fixed elevation.

A mixture of air and water makes a troublesome combination in a pipe on account of the ease with which



FIG. 7.—Irrigation layout of wood stave pipe for deciduous orchard near Grandview, Wash.

In addition to gates, valves, outlets, and fittings, successful pipe systems usually include special equipment. When the outlets of a long line of concrete pipe on a steep grade are open, the pressure may be wholly removed;

air is compressed and expanded. To rid water of this air, valve-controlled openings are made in pipe lines at high points where air collects. The openings in irrigation hydrants which supply water to furrows are small and are readily clogged by sand, leaves, or other material, to exclude which sand traps and screens are inserted at suitable points in the pipe system.

<sup>5</sup> For a determination of the capacity of concrete pipe, see U. S. Dept. Agr. Bul. 852, "Flow of water in concrete pipe," by F. C. Scobey.



ance with the efficiency of the irrigation system, the amount of money expended, the skill used in installation, and the orchard's value and average annual profits.

Expensive devices for distributing water into furrows are not warranted in orchards of little value and small annual returns. On the other hand, it may prove an economical investment to provide valuable orchards, yielding high annual returns, with the best-known devices for successful irrigation. Such equipment is unquestionably some form of underground pipe fitted with suitable standpipes, such as have already been described.

#### EARTHEN HEAD DITCHES

Permanent ditches at the head of orchard tracts should be located by

The chief difficulty in this mode of furrow irrigation arises in withdrawing water from the ditch and in distributing it equally among a large number of furrows. A skilled irrigator may adjust the size and depth of the ditch bank openings so as to obtain a somewhat uniform flow in the furrows, but its maintenance requires frequent attention. If the water is permitted to flow unattended for a short time, the distribution is likely to become unequal. Parts of the ditch bank become soft, and, as the water rushes through, the earth is washed away, permitting larger discharges and lowering the general level of the water in the ditch so that other openings may have no discharge. Some of the orchardists of San Diego County, Calif., insert in niches cut in the bank pieces of old grain sacks or tent

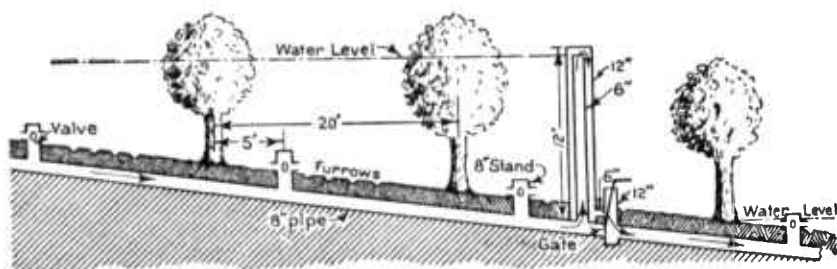


FIG. 9.—Use of underground pipe in furrow irrigation, showing riser and stand

a surveyor. The proper grade depends chiefly on the soil. If the soil is loose and easily eroded, a slow velocity is best. On the other hand, the velocity must be rapid enough to prevent the deposition of silt and the growth of water plants. In ordinary soils, a grade of  $2\frac{1}{2}$  inches to 100 feet for a ditch carrying 2 cubic feet per second is about right. The quantity of water to be carried varies from one-half to 2 or more cubic feet per second. A ditch having a bottom width of 24 inches, a depth of 6 inches, and sloping sides, ought to carry  $1\frac{1}{2}$  cubic feet per second on a grade of half an inch to the rod or 3 inches to 100 feet. Such a ditch may be built by either shovels or a narrow scraper. The loose earth likewise may be thrown up on the sides and top by means of an A-crowder. Metal tap-poons or other similar devices are inserted in the head ditch to raise the surface of the water opposite that part of the orchard where furrows have been made and which is about to be watered.

cloth. The water flows over these without eroding the earth. Another plan is to use a board pointed at the lower end and containing a narrow opening or slot through which the water passes to the furrow. Shingles are also used to regulate the flow in the furrows. The thin ends of these are stuck into the ground at the heads of furrows. In some of the orchards of Colorado the flow into the head of each furrow is regulated by a small gate, as shown in Figure 12.

#### HEAD FLUMES

Although earthen head ditches are still much used in conveying water to orchards, there are conditions in which they are either unsuitable or uneconomical, or both. Earthen ditches are unsuited to steep slopes or to porous soils. Even in medium soils the loss of water resulting from seepage and absorption is too great wherever water has a high value. To economize in water and facilitate its distribution, a flume may be substituted

for the earthen ditch. The length of the sections of a wooden flume varies from 12 to 20 feet, 16 feet being the most common. The bottom width is from 6 to 12 inches, and the depth usually is 1 to 2 inches less. Redwood lumber  $1\frac{1}{4}$  inches thick is suitable for the bottom and sides, although creosoted fir lasts longer; and joists of 2 by 4 inch pine or fir are commonly used for yokes, which are spaced 4 feet. Auger holes are bored midway between the yokes and the flow through these openings is controlled by small metal gates sliding over the holes between grooves. A

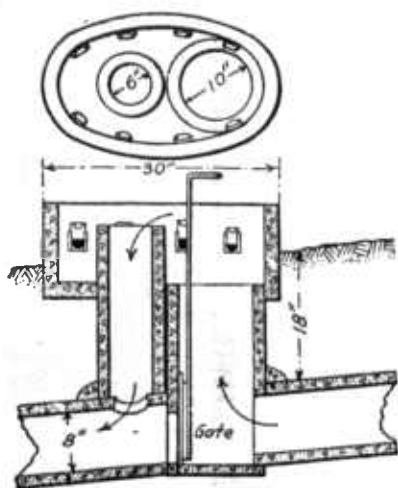


FIG. 10.—Stand used in distributing water to furrows

2-inch fall for each 100 feet may be regarded as a suitable grade for head flumes, but it often happens that the slope of the land is much greater than this, in which case low checks are placed in the bottom of the flume at each opening. Formerly many head flumes in southern California were built of concrete, but concrete pipes have been found more serviceable and there have been few installations of concrete head flumes during the past decade. An outline of the form of flumes of this type is shown in Figure 13.

For large head ditches and laterals, some fruit growers first smooth and grade an earthen ditch which has carried water for at least one season and afterwards line the inner surface with concrete.

#### SHORT TUBES IN HEAD DITCHES

Short tubes or spouts have been used in many of the head ditches of

orchards to divert small quantities of water to furrows. These tubes usually are made of wood; but pipes made of clay, black iron, galvanized iron, and tin are used occasionally.

For nurseries and young trees especially, but also for mature trees, a cheap and serviceable tube may be made with ordinary pine laths. The 4-foot lengths are cut into two equal parts and four of these pieces are nailed together to form a tube. In southern Idaho the lumber mills make a special lath for this purpose. It is one-half inch thick, 2 inches wide, and 36 inches long. If such tubes when thoroughly dry are dipped in hot asphalt they will have a much longer life.

The orchardist who lives near a manufacturing city often can purchase cheaply pieces of worn-out and discarded piping varying from three-fourths inch to 2 inches in diameter. Such pipes when cut into suitable lengths substitute satisfactorily for wooden spouts. Tin tubes one-half inch in diameter and of the proper length have been used with good success. In compact soils the furrows must be near together, and small tin tubes are to be preferred.

In making use of tubes to distribute water to furrows it is necessary to maintain a constant head in the supply ditch. This is done by inserting checks at regular distances. These distances vary with the grade of the ditch, but 150 feet may be considered an average spacing. In temporary ditches the canvas dam is perhaps the best check, but in permanent ditches it pays to use wood or concrete. An effective wooden check is shown in Figure 14. The opening is controlled by a flashboard which may be adjusted so as to hold the water at any desired height and at the same time permit the surplus to flow over the top to feed the next lower set of furrows.

#### IRRIGATION FURROWS FOR ORCHARDS

The length of furrow is governed by the irrigation layout. Past practice has generally countenanced furrows of excessive length. A square 10-acre tract was considered a convenient subdivision because it formed a unit of the standard land surveys. After deducting the width of farm lanes, the length of furrow in such a tract exceeded 600 feet. This has proved to be too long for efficient irrigation in ordinary soils, and many orchards have been subdivided by a head ditch, flume, or pipe at their mid points, so

reducing the length of furrows to about 300 feet. Where the soil is porous, the division of a 10-acre tract into three equal parts, reducing the length of run in each 200 feet, may be advisable; but in heavy soils, through which water passes slowly, a furrow length of 600 feet may be preferable.

The grade of furrows varies widely. In flat valleys it often is not possible to obtain a fall greater than 1 inch to 100 feet, whereas on steep slopes the fall may reach or in some cases greatly exceed 2 feet per 100 feet. On ordinary soils a grade of 4 to 6 inches to 100 feet is to be preferred, and where the slope of the land exceeds 2 feet in 100 feet the trees should be set out in such a way as to reduce the grade of

row with a furrow on each side, and cross furrows are then made  $2\frac{1}{2}$  to 3 feet apart (fig. 17).

A common type of furrowing implement is shown in Figure 18. It consists of a sulky frame to which are attached two double moldboard plows. A somewhat similar implement known as the "Montrose marker" (fig. 19), is used for furrowing orchards in Colorado. It will be noted that the blades of the furrower have a barbed or hooked shovel fastened to their bottom apex, the purpose of which is to shape the furrow while the wings form the banks.

Those who prefer a small number of deep furrows use a 12 to 14 inch corn lister. A single-blade furrower

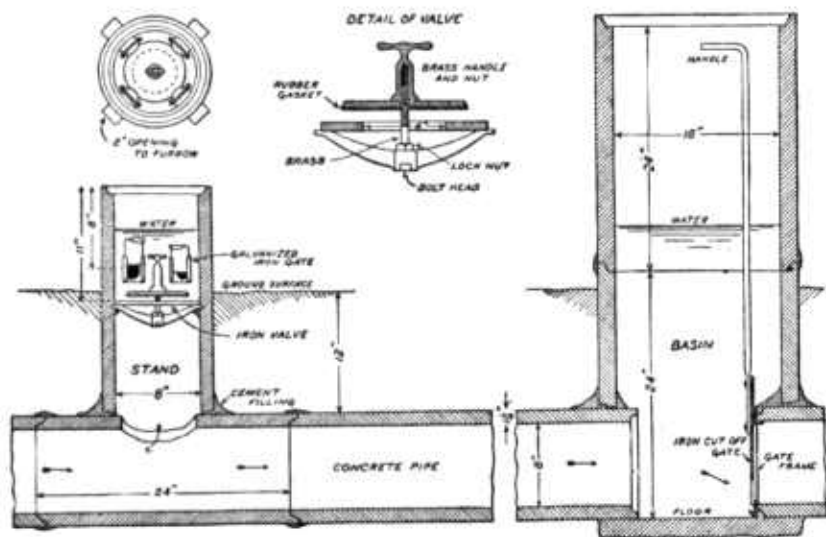


FIG. 11.—Design of concrete pipe and stand system for orchard irrigation

the furrows. The soil erosion shown in Figure 15 is a result of too steep a grade.

The number of furrows and their spacing depend on the age of the trees, the space between tree rows, the growing of cover crops and intercrops, the depth of furrow, and the character of the soil. Nursery stock and young trees are irrigated by two furrows (fig. 16).

As the trees grow and the roots expand, more furrows should be added. For citrus and deciduous orchards in bearing, four or five furrows between the rows are common. For wide-spaced walnut trees a ridge is sometimes made in the middle of the tree

used by some of the orchardists near Canon City, Colo., is illustrated in Figure 20.

#### RUNNING WATER IN FURROWS

It is difficult to supply the needed moisture to the tree roots of an orchard by means of furrows. In increasing the lateral spread of the roots by the lure of moist soil, it is also possible to increase the depth. The object of the grower should be to provide the largest possible feeding ground for the roots. Furrows parallel to the tree rows are adapted to young orchards, but when the trees reach maturity their branches occupy

more of the open space between the rows and prevent the making of furrows near the trees. This is shown in Figure 21, where a space with the tree row in the center is not furrowed. This space, which is 6 to 12 feet wide, depending upon the size of the trees, usually becomes so dry that it is worthless as a feeding ground for roots. To moisten such dry spots, a

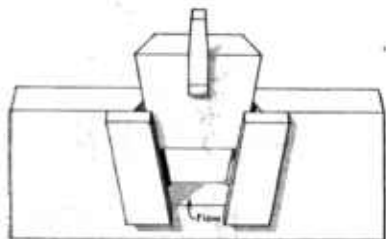


FIG. 12.—Small wooden gate used to control flow in furrows in orchard irrigation in Colorado

larger stream often is carried in the two furrows next to each row of trees, and the surplus is led across furrows (fig. 22). Instead of continuing straight and cross furrows, as illustrated by Figure 22, use frequently is made of diagonal furrows to moisten

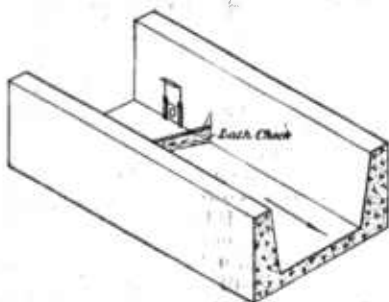


FIG. 13.—Use of low check in head flume

the dry space between the trees. This method is best adapted to grades of 5 inches or more per 100 feet.

In one method the implement used to make furrows consists of three shovels attached to a beam, which is mounted on a pair of low wheels. The driver, who sits on a riding seat, by operating a lever can regulate the depth of the furrows. A man and two horses will furrow out 10 acres in a day. For 150 feet from the top of the orchard the furrows are straight. They are then zigzagged to within 60 or 70 feet of the bottom, where the last three rows of trees are irrigated

by basins which catch the surplus. In the case described the depth of furrow was 6 inches, length 800 feet, and distance apart 3 feet. A head of 1 cubic foot per second was used on 10 acres. The streams when first turned into the furrows averaged about one-twenty-fifth cubic foot per second, but as the water approached the lower end they were reduced to half this quantity or less, and this flow was run in each furrow for 12 to 24 hours.

Furrow irrigation varies with topography, soil, water supply, and other conditions. In Yakima County, Wash., most furrows in mature orchards are  $3\frac{1}{2}$  to 4 feet apart and are about 8 inches deep. Water is allowed to run in the furrows from 12 to 48 hours,

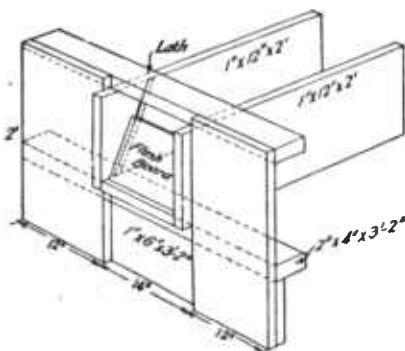


FIG. 14.—Wooden check in head ditch

the longer time being required for the heavier soils, for long runs, and for very steep slopes of furrows.

In the Payette Valley, Idaho, 4 cubic feet per second are turned into the head ditch and divided among four furrows by means of wooden spouts. On steep ground much smaller streams are used. The length of the furrow varies from 300 feet on steep slopes to 600 feet and more on flat slopes. The time required to moisten the soil depends on the length of the furrow and the nature of the soil. In this locality it varies from 3 to 36 hours.

A 20-acre orchard tract under the Sunnyside Canal in Yakima Valley is watered four times in each season with one-third cubic foot per second. Three furrows are made between the rows, which are 40 rods long. The total supply is applied to one-half the orchard (10 acres) and kept there 48 hours.

On the clay loams of the apple orchards on the east bench of the Bitter-root River, Mont., it requires from 12 to 18 hours to moisten the soil 4 feet deep and 2 feet laterally from furrows.

An orchardist of Hood River, Oreg., irrigates 3 acres of apple trees in furrows 350 feet long, spaced 3 feet apart. About one-fiftieth cubic foot per second of water is turned into each alternate furrow from a wooden head thume and kept there about 48 hours. After the soil has become dry enough it is cultivated, and 8 or 10 days later water is turned into the rows which were left dry during the first irrigation.

A common method of furrow irrigation in the orchards of the foothills of the Sierras in Placer County, Calif., is to run one furrow down the steepest slope for each row of trees, curving it around each tree in the row in the manner illustrated by Figure 23. Ordinarily the length of the furrows is not more than 600 feet and water is allowed to run in each from 24 to 48 hours every two weeks. Occasionally furrows are located on a curved water grade, but this method involves the risk of a furrow becoming clogged so that the water breaks its bank and



FIG. 15.—Soil erosion in furrows on too steep grades

also the banks of the lower furrows of the series, resulting in soil erosion.

Furrow irrigation in orchards having the trees planted on curved water grades differs in some respects from that of orchards planted in squares or triangles on flatter land. On account of the steepness of the planted slopes

and the damage which uncontrolled water is likely to do, head ditches in earth are not safe. Pipes, lined ditches, or thumes should be used. Shorter furrows are also desirable. A length of 300 feet in the lighter soils and 400 feet in the heavier soils should rarely be exceeded. In shallow



FIG. 16. Furrow irrigation of young orchard trees in Idaho

soils underlain by a more impervious soil stratum, water tends to move down the slope on top of the layer of subsoil, and this movement lessens the number of furrows required. The quantity of water turned into each furrow varies widely. Sometimes it is limited to one-half gallon per minute. At other times one-fiftieth cubic foot per second may not be too much. The usual practice is to turn a comparatively large quantity into each furrow. When the water has almost reached the lower end the flow is reduced, the purpose being to regulate the subsequent flow in such a way that it will be equal to the water absorbed by the soil over the length of the furrow.

#### DISTRIBUTION OF WATER FROM FURROWS

In furrow irrigation the small stream which flows in each furrow is absorbed by the soil in its passage from the upper to the lower end. On account of the action of gravity the distance water penetrates downward

in a uniform soil is greater than that sidewise. Long furrows in porous soils waste much water by deep percolation in their upper lengths. An experiment at Riverside, Calif., permitted a study of distribution of water from furrows in several 10-acre orange groves. The trees were about 10 years old and spaced in squares 20 to 22 feet apart. Under favorable subsoil conditions, the bulk of the roots were found above the 4-foot level, but a limited number extended beyond the sixth foot. On one tract of sandy-loam soil the percolation of water downward from furrows 660 feet long was 26 feet near the upper

as shown in Figure 25; but on flat land as many as 25 trees may be included, the number depending on the spacing of the trees, the slope of the tract, and the head of water. If the trees are spaced 24 feet apart and the land slopes 2 inches in this distance, only one tree should be included. On the other hand, if the maximum slope is not much more than 2 inches in 48 feet, four trees may be included. Similarly, if the trees are spaced 20 feet apart and the slope does not exceed  $2\frac{1}{2}$  inches in 100 feet, 25 trees may be included in one basin. The larger the basin the larger the head of water required. A head of 1 to 2



FIG. 17.—Cross furrows in walnut grove

end and  $4\frac{1}{2}$  feet near the lower end. After digging trenches across the furrows and by-passing the flow, the rate of moisture penetration could be observed and recorded. The distribution of water from furrows between four rows of trees of an orchard containing somewhat typical soil and subsoil conditions is shown in Figure 24.

#### THE BASIN METHOD

This method of irrigating orchards planted in squares is well adapted to light and medium soils on rather flat slopes where fairly large heads of water are available. The most common practice is to inclose each tree in a basin formed by throwing up a ridge around the rectangular inclosure,

second-foot is the best for small basins, but 3 to 4 second-feet are needed for the large ones.

Earthen head ditches, wooden flumes, or underground-pipe systems may be used to distribute the water to the basins much as for furrow irrigation, except that the number of outlets in basin irrigation is necessarily considerably less. One outlet may readily be made to serve two tiers of basins by making the opening at the common corner, although some growers provide an outlet for each tier.

Several kinds of implements are used to make ridges. If the grower has nothing better, a single moldboard plow having a sheet of metal fastened to the top to keep the earth

from spilling over, will answer the purpose. An adjustable home-made ridger is shown in Figure 26. It consists of two deep runners 14 to 18 inches high, 2 inches thick, and 6 to 8 feet long. These runners are shod with steel which extends part way up the inner side. They are 4 to 5 feet apart at the front end and taper to 16 to 24 inches at the rear. The runners are held in position by cross-pieces on top, a floor, and straps of steel.

In many of the larger orchards, tractors now do much of the work

A ridge 3 feet wide at the base and 14 inches high should hold water to a depth of 7 inches.

The University of California has demonstrated by experiments at Davis that basins may be adjusted to meet the water requirements of young

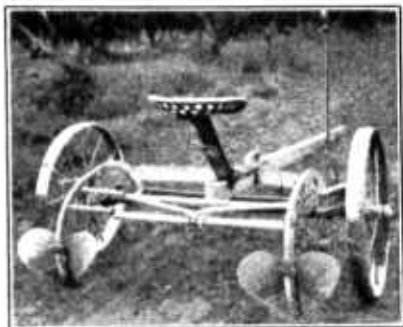


FIG. 19.—The Montrose marker used in making furrows in Colorado orchards

trees. Stated in another way, basins may be so formed as to irrigate only a little more than the soil of the root zone. This practice is similar to the use of a small number of furrows in the irrigation of immature trees by the furrow method. In the sketch (fig. 28) 3-year-old prune trees planted 24 feet each way are irrigated by



FIG. 18.—Making furrows in orchard

formerly done by horses and mules. This change in power has necessitated corresponding changes in equipment. A ridger operated by a tractor is shown in Figure 27. It was designed by a fruit grower of Cupertino, Calif. and consists in the main of a heavy frame of plow-beam sections, two wheels, two disks 26 inches in diameter, a set of levers, and a seat for the operator. The implement weighs over 600 pounds and costs \$200. A reversible disk harrow may be made to serve the same purpose.

The form and size of the ridges are influenced by the implement making them. They should be large enough to retain the required depth of water.

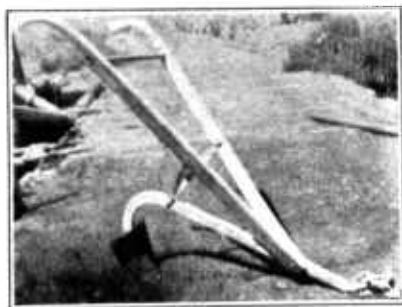


FIG. 20.—Implement used by orchardists of Canon City, Colo., in making furrows

basins each 16 by 24 feet, thus leaving a dry space 8 feet wide in the center between the tree rows. On the basis of cost of water and all operations connected with its application, this method saved 20 per cent of the expenditure required for the complete irrigation of the orchard tract.

Water may be applied to basins in any one of three ways. One way allows the water to flow through the

basins until the lowest is reached. This is filled first; it is then closed, the next lowest is filled, and the process continued until the basin adjacent to the head ditch is reached and filled.

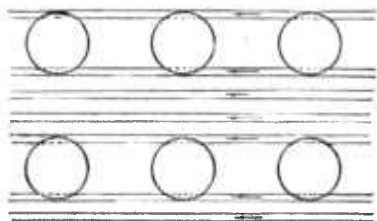


FIG. 21.—Furrow irrigation, showing dry spaces

In another way the procedure is reversed by filling the highest basin first and allowing the excess water to spill over into the second, and so

basins first. Again, those who object to the inconvenience and difficulty of irrigating on wet ground, strive to keep their feet dry by beginning at the top tier of basins and working downward.

A common distance to run water in basin irrigation is 240 feet, or a length of 10 trees 24 feet apart. A head of three-fourths second-foot is about the smallest flow that can be used to advantage in such a case. Heads of 1 to 2 second-feet are preferable, and where eight or more trees are inclosed within a single basin a discharge of 3 second-feet is not too large. Flooded basins are shown in Figure 29.

After an irrigation and prior to cultivating or seeding to a cover crop, the ridges are leveled or "broken," as the process is termed. This reduction to the original flat surface may



FIG. 22.—Check-back furrow irrigation in citrus orchard

on until all are filled. In both of these the upper basins receive more than an equal share, and it was to remedy this defect that the third way was devised. In this, water is run in a ditch between every two basins and the flow is admitted to each basin in turn until all are filled.

Sometimes the grower is confronted with conditions which cause him to adopt a particular method. This happens when there is hardpan or other impervious stratum below the surface soil. Under such conditions it is best to begin to fill the upper

basins first. Again, those who object to the inconvenience and difficulty of irrigating on wet ground, strive to keep their feet dry by beginning at the top tier of basins and working downward.

#### THE SPRINKLING METHOD

During the past 15 years, truck crops and to a less extent orchards, grown in several of the Atlantic Coast States, have been irrigated by the spray method.<sup>6</sup> Since 1922, modified forms of the same method have been

<sup>6</sup> WILLIAMS, MILO B. SPRAY IRRIGATION. U. S. Dept. Agr. Bul. 495. 40 pp., illus. 1917.

used in irrigating citrus orchards in several localities of southern California. All sprinkling is done there in circles of varying diameters, from a sprinkling head, fixed or rotary, in the center of each. Water is supplied from pipes under pressure. Installations are said to be either permanent, portable, or semiportable. In the permanent type, small piping is laid underground along every second, third, or fourth tree row, or, sometimes, either midway between the tree rows or along the edge. Vertical pipes or "risers" with a sprinkler attached to the upper end of each are installed

of the riser. The circular spray from this type covers much less ground than that from the rotating head type.

The initial cost (1925) of installing these systems, exclusive of the cost of the pumping equipment necessary to produce the required pressure, is approximately \$300 per acre for the permanent type, \$90 for the semiportable, and \$60 for the portable.

### WATER REQUIREMENTS OF ORCHARDS

The experience gained by many western growers during the last 25 years over a large and diversified



Fig. 23.—Furrow curved around tree, illustrating practice in foothill orchards

at equidistant points on each pipe line. Each riser has a valve to regulate the pressure and a strainer to catch sediment or pipe scale.

To lessen the first cost of installing the many risers and to reduce the number of pipe lines, portable risers attached to short lines of hose may be used, this arrangement constituting the so-called portable system.

The semiportable system usually involves laying a pipe line along every sixth tree row and installing risers and garden hydrants at every sixth tree. In other cases a permanent feed pipe is laid through the middle of the orchard, and lateral pipes on the ground surface convey the water to portable hydrants.

Two types of sprinkling heads are manufactured. The so-called "solid" head is a perforated cap of brass alloy which is screwed tightly into the top

territory has established the belief that there is a close relation between irrigation and the size, quality, yield, and commercial suitability of fruit. In most localities where fruit growing is an important part of farming, the rainfall is too scanty to produce the most profitable yield. It may suffice to nourish young trees, but when they begin to bear marketable crops the natural water supply needs to be supplemented mainly because of the increased transpiring surface of the tree. Many orchards have been planted in the belief that irrigation would not be necessary; but the small size of the fruit, coupled with the low yields, have convinced the growers that the rainfall did not furnish adequate soil moisture. On the other hand, the writer does not know of even one orchard that at first was irrigated which afterwards depended upon the

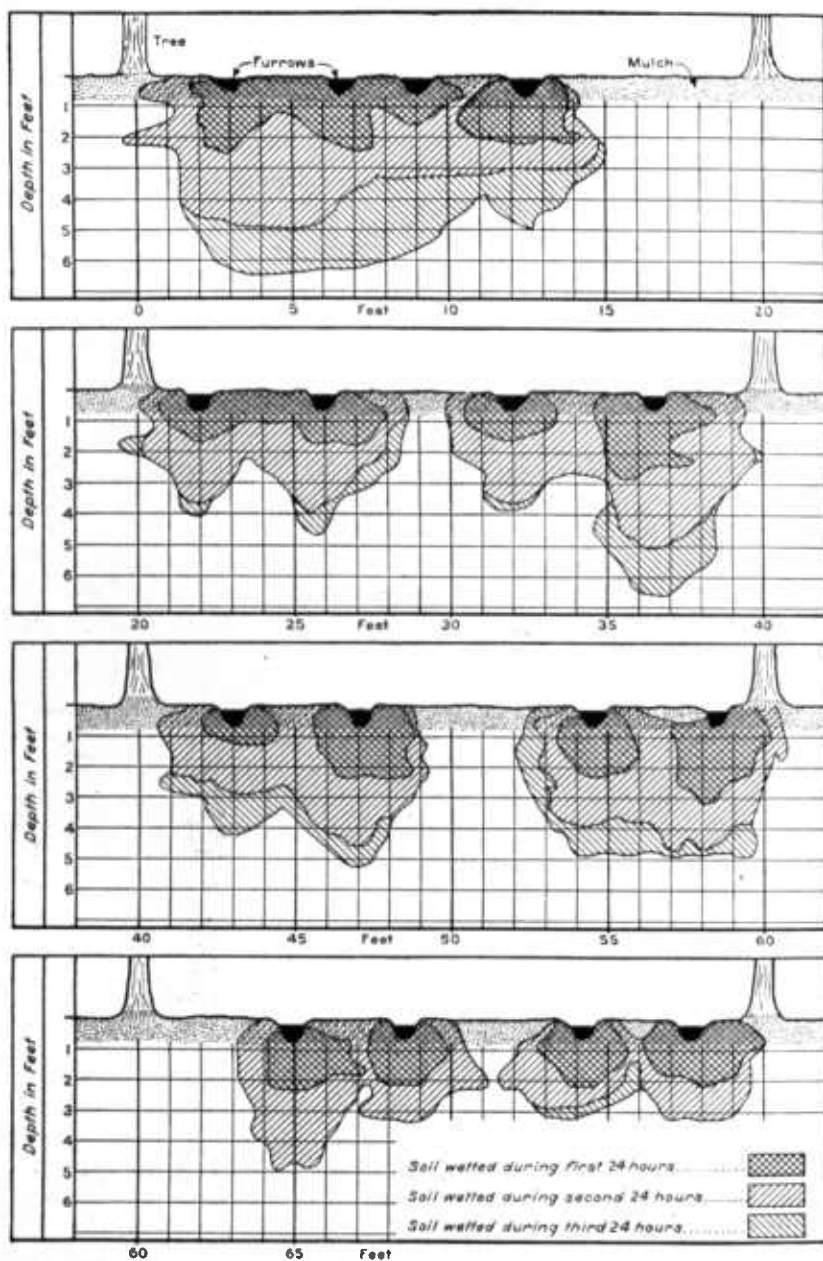


FIG. 24.—Distribution of water from 16 consecutive furrows, showing daily progress of saturation of a sandy-loam soil near Riverside, Calif.

natural precipitation alone. With few exceptions, the quantity of fruit produced, its quality as judged by the shipper and consumer, its suitability for canning and drying, and the regularity of bearing, are influenced favorably by the proper use of irrigation water. The exceptions to this general condition occur usually when too much water is applied, when the soil is watered at the wrong time, when the distribution of water is uneven, or

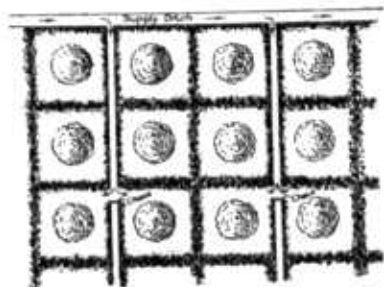


FIG. 25.—Basin method of irrigation

when through lack of proper control the water table rises into the root zone.

The water requirements of orchards are influenced by a score or more of conditions chief of which are climate, soil, age of trees, intercrops, and cover crops. As regards climate, temperature and intensity of sunlight determine the quantity of irrigation water which must be applied to supplement the natural precipitation. There is sufficient rainfall in some localities for small trees. For years not much irrigation was practiced in the deciduous orchards of Santa Clara Valley, Calif. Here the normal rainfall is about 16 inches on the floor of the valley, with more on the foothills. However, as the trees became larger, the need for water increased, and at present perhaps 90 per cent of the orchards are irrigated. The fruit growers of Rogue River Valley, Oreg., have had a similar experience. At first they got along with about 20 inches natural precipitation, but in the last few years no less than six irrigation districts embracing a total area of 40,000 acres have been organized to finance development of supplemental supplies.

Temperature is also an important factor, the growing season being relatively short in the colder parts of the West and the demands of trees for water correspondingly low.

Soils on which orchards are planted range from the gravelly loam to the heavy clays. The former, because of their low retentive capacity and the readiness with which water passes through them, require more water than the latter.

The roots of young trees are confined to a much smaller area than those of mature trees; but, in growing intercrops and cover crops, a double duty is imposed on the soil of the orchard and the water requirements of the tract greatly increase.

The water use per acre as fixed by water contracts varies all the way from one-fortieth to one-four-hundredth of a cubic foot per second. In general, the most water is applied in districts that require the least. Wherever water is cheap and abundant the tendency seems to be to use large quantities, regardless of the requirements of the fruit trees. In Wyoming the duty of water is seldom less than a cubic foot per second for 70 acres.

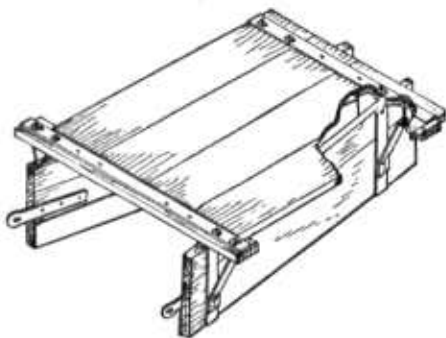


FIG. 26.—Adjustable home-made ridger

In parts of southern California the same quantity of water not infrequently serves 400 acres, yet the quantity required annually by the fruit trees of the latter locality is greater than that of the former.

On the Sunnyside division of the Yakima Irrigation Project, Wash., in which nearly 15 per cent of the total area is in fruit, the average monthly use of water on all crops for a nine-year period (1916-1924) was, in acre-feet per acre, 0.3 in April, 0.58 in May, 0.57 in June, 0.6 in July, 0.61 in August, 0.4 in September, and 0.2 in October, making a total seasonal use of 3.26 acre-feet per acre, which, with 0.22 acre-feet of summer rainfall, increased the water use to 3.48 acre-feet per acre.

On the Tieton division of the same project, with more than half its area in fruit, less water is used. The monthly averages in acre-feet per acre, for the same year were 0.06 in April, 0.5 in May, 0.49 in June, 0.51 in July, 0.53 in August, and 0.36 in September, or a total of 2.45 acre-feet, which, with 0.17 acre-feet of summer rain, made a season's use of 2.62 acre feet per acre. In both the divisions cover crops were grown in most of the orchards.

In 1908 the depth of water used on a 21½-acre apple orchard at Wenat-



FIG. 27.—Ridger operated by tractor

chee, Wash., was 23 inches. The trees were 7 years old and produced heavily. This orchard was watered five times, the first on May 13 and the last on September 23. In San Diego County, Calif., 12 to 15 acre-inches per acre are used to irrigate citrus orchards near the coast where the air is cool and evaporation low, but 20 miles or so inland 20 to 24 inches are required.

On the sandy loam orchards of Orange County, Calif., an average practice calls for about 4 acre-inches of water every 60 days. The rainfall of this locality averages somewhat less than 12 inches per annum, but about 95 per cent of the total falls between November and May, inclusive.

Over 90 per cent of the water supply of the Temescal Water Co. of Riverside County, Calif., is pumped from wells. Table 5 shows the yearly quantities of water per acre which this company delivered to the citrus groves at Corona, Calif., during each of the years named, the length of the irrigation season, and the interval between water deliveries.

TABLE 5.—Quantity of water delivered yearly by Temescal Water Co., California

Year	Quantity of water delivered per acre	Interval between water deliveries	Length of irrigation season
	<i>Acre-feet</i>	<i>Days</i>	<i>Days</i>
1917.....	2.19	27	288
1918.....	2.04	30	290
1919.....	1.85	30	280
1920.....	1.70	27-30	252
1921.....	1.65	30-35	250
1922.....	1.65	25-30	224
1923.....	2.06	25-30	291
1924.....	2.05	30-33	293

### INTERCROPS

Intercrops, or crops grown between the rows of nonbearing trees, and cover crops, or those grown to fertilize and improve the soil, influence the

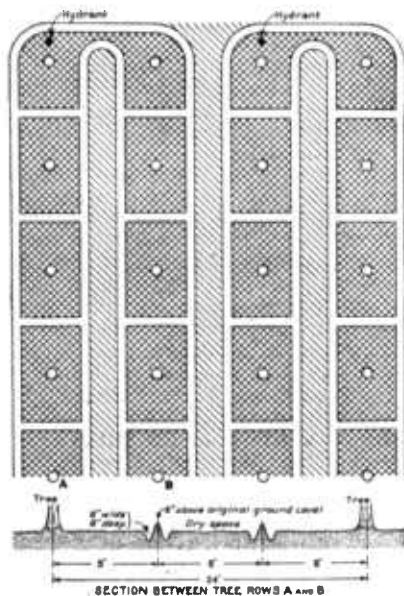


FIG. 28.—Basin irrigation of young trees. Double-ruled areas irrigated, single-ruled areas dry

quantity of water used on orchards, the frequency with which it is applied, and, to a less extent, the method used in wetting the soil. Years ago the clean culture of orchards had many advocates, especially in California. They regarded fruit growing as a long-time investment involving heavy out-

lays until the trees began to bear. The anticipated later profits were supposed to compensate for the intervening lean years.

The experience gained in the last decade has convinced most growers that intercrops may be grown in young orchards with profit to them and without injury to the trees, providing cover crops take the place of intercrops before the trees produce in quantity. The adoption of this plan is dependent upon an adequate and reasonably cheap water supply. Where water is scarce and costly intercrops may not pay.

Intercrops are usually irrigated in furrows, the quantity of water applied

and less frequently after the fruiting period, strawberries requiring frequent irrigations. The seasonal application is large but the trees have not been injured by it. The usual method of irrigating intercropped strawberries is shown in Figure 31.

In Yakima Valley, Wash., intercropping in young orchards is the general practice; corn, alfalfa, potatoes, squash, and melons being the intercrops most commonly planted. The quantity of water applied is adapted to the needs of the intercrop, rather than the trees.

The intercropping of peach and cherry trees for three to four years and of apple trees for five to six years



FIG. 29.—Flooding basins

and the frequency of irrigation depending on the kind of crop, summer rainfall, and character of the soil.

In Hood River Valley, Oreg., the practice for years has been to grow strawberries between the rows of non-bearing apple trees. The berries are planted in rows 30 to 36 inches apart and spaced 14 to 18 inches in the row, all runners being cut off as they appear. In some cases a row of strawberries is planted in the tree row. The usual life of strawberry plants is four to five years, and when set out at the same time as the trees they last until the trees begin to bear, which marks the end of the intercropping period. The first irrigation follows the last spring rains, and light waterings are applied thereafter twice a week throughout the picking season

is common practice in Box Elder County, Utah, and does not appear to be injurious to the trees. Tomatoes grow well in that locality and they are used frequently as an intercrop. Five rows of tomatoes are grown in the tree space; but, when the trees approach bearing age, beans are almost the only crop planted because of their partial immunity from the injurious effect of shade.

In San Joaquin Valley, Calif., four to six rows of cotton are planted between the rows of young trees with highly satisfactory results, and the trees seem to do well.

In Orange County, Calif., six to eight rows of Lima beans are planted between the rows of citrus trees and the same intercrop is preferred by the owners of young walnut orchards.

## COVER CROPS

The purpose of growing cover crops in orchards being to increase the organic ingredients of the soil and incidentally to increase the water holding capacity of the soil and improve its texture, they differ from intercrops in usually being planted in bearing orchards, and the roots of trees and those of cover crops have a common feeding ground. Accordingly, care and good judgment should be exercised in preventing, in so far as is practicable, competition between the roots of cover crops and those of the trees for the common supply of moisture and food. As for moisture for cover crops, advantage is taken of the winter rainfall and high winter temperature of the Pacific Coast States to plant in the fall and turn under the crop in the spring in time for the most active stage of tree growth. In Yakima Valley, Wash., most of the light yearly

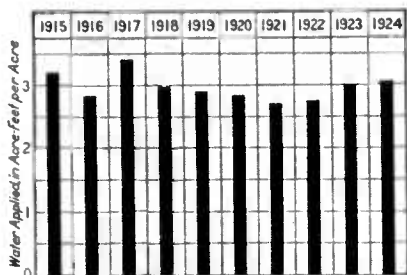


FIG. 30.—Quantity of water, by years, used per acre under Gage Canal in Riverside County, Calif.

precipitation occurs in winter, and cover crops of alfalfa, sweet clover, red clover, and vetch are grown. In many orchards of California and the Southwest, vetch and melilotus are favorite winter cover crops. Vetch is planted in September in central California while the weather is still warm and the deciduous trees are approaching dormancy. It makes a rapid growth, particularly in March, and is turned under while green. The orchard is then clean-cultivated and irrigated throughout the irrigation season. It receives a light irrigation in the fall before the vetch is seeded, but thereafter gets only the winter rainfall until the following spring.

In Santa Clara Valley, Calif., where basin irrigation is practiced, melilotus is planted on the floor of each basin. Then the basins are irrigated to germinate the seed. Vetch is sown on the ridges of the basins and both crops are plowed under in the spring.

Formerly the clean culture of orchards without cover crops was quite generally practiced in the Rocky Mountain States, but this resulted in a depletion of the vegetable matter in the virgin soil, a falling off in the yield of fruit, and the formation of a hard and lifeless top soil. The growers first thought of alfalfa as a remedy, and it has become the most common cover crop there, as in the Northwest. However, there are objections to its use for this purpose. Because of the long time it takes alfalfa to mature, the readiness with which it can be handled as a hay crop, and the difficulty with which it is eradicated, the grower is induced to maintain a permanent sod in his orchard, so depriving the soil of the fertilizer it would receive, were the crop turned under. The better practice is to alternate alfalfa or clover with clean culture during biennial periods. In Colorado, rye, winter oats, and hairy vetch are sown in the fall and plowed under in the spring. According to Valle<sup>7</sup> the use of winter green-manure crops in citrus groves in California increased from 40,000 acres in 1914-15 to 100,000 acres in 1916-17.

Hodgson<sup>8</sup> says that "the cover crop is unquestionably of considerable value where a reasonable tonnage can be grown without competing with the trees" for either nitrogen or water. Where the smallest quantities of manure were used, the cover crop increased the yield about 20 per cent. Where the largest quantities were used the least effect from the cover crop was an increase in yield of 6 per cent.

## TIME AND FREQUENCY OF IRRIGATION

The time and frequency of fruit-tree irrigation depend primarily on the soil-moisture conditions within the root zone. The depth and spread of the roots is of importance in this connection. Little or no available moisture may be found in the top foot of soils supporting a vigorous tree growth. This is particularly true of some localities in the Southwest where the summer temperature is high and the evaporation excessive.

It is difficult to determine the lower limits of root zones, especially in deep

<sup>7</sup> VAILE, ROLAND S. A SURVEY OF ORCHARD PRACTICES IN THE CITRUS INDUSTRY OF SOUTHERN CALIFORNIA. P. 19. Univ. of Calif. Coll. of Agr., Agr. Exp. Sta. Bul. 374.

<sup>8</sup> HODGSON, ROBERT W. FERTILIZING CITRUS TREES IN CALIFORNIA. P. 15. Univ. of Calif. Coll. of Agr., Agr. Exp. Sta. Circ. 283.

subsoils of good texture. Investigators have been led astray by assuming a depth of roots of, say, 6 feet, and basing conclusions thereon, where as a matter of fact a small number of the leading roots may have penetrated the soil to twice and three times this distance.

Although the time of applying water is governed by the quantity of soil moisture in the root zone, it does not follow that this moisture content should be constant so long as moisture available for the tree's use is present in the soil. The successful grower tries to gauge the quantity applied

ing with straw and other materials, protection by means of windbreaks, and a reduction of leaf area by moderate spring pruning."

Some diseases of orchard trees may be controlled in a measure, and frequently an injury prevented, by judicious irrigation. Thus, the fall and winter irrigation of walnut groves has sometimes been an effective means of forestalling die-back or the death of top branches.

Soil tubes and other equipment designed for the determination of soil moisture should be more generally used in valuable orchards. By means



FIG. 31.—Irrigation of strawberries in young orchard

and the interval between waterings to the need of both trees and soils.

There is a close relation between irrigation and certain unfavorable weather conditions. The effect on winter killing is discussed elsewhere in this bulletin. The June drop of navel oranges is often attributed to a lack of soil moisture. Colt and Hodgson,<sup>9</sup> for example, conclude that "practical means of amelioration lie in heavier and more frequent irrigation, the planting of intercrops, mulch-

ing with straw and other materials, protection by means of windbreaks, and if the sample be weighed and oven-baked, its moisture content can readily be found. This requires no extraordinary skill, and the results are much more reliable than mere guesses.

The best orchardists believe that frequent examination of the stem, branches, foliage, and fruit is not enough. The roots and soil should be examined also. The advice to the inexperienced is: Find out where most of the feeding roots are located, ascertain the nature of the soil around them, and make frequent tests of the moisture it contains.

<sup>9</sup> COLT, J. ELIOT, and HODGSON, ROBERT W. AN INVESTIGATION OF THE ABNORMAL SHEDDING OF YOUNG FRUITS OF THE WASHINGTON NAVAL ORANGES. *Ag. Sciences, Univ. of Calif.*, vol. 3, No. 11.

Many fruit growers do not turn on the irrigation stream until the trees begin to show signs of suffering, such as a slight change in color or a slight curling of the leaves; but waiting for such signals of distress is likely to cause injury to both trees and fruit. On the other hand, the application of large quantities of water whenever it is available is likely to be even more harmful.

For nearly half the entire year the fruit trees of Wyoming and Montana have little active, visible growth, whereas in the citrus districts of California, Arizona, and Texas the growth is continuous. The quantity of moisture evaporated from both soil and tree in winter is relatively small because of the low temperature, the lack of foliage, and feeble growth. A heavy rain which saturates the soil below the usual covering of soil mulch may take the place of one artificial watering. The number of irrigations likewise depends on the water-holding capacity of the soil. If it has low moisture capacity, light but frequent applications will produce the best results; but if its capacity is high, heavy applications at longer intervals are best.

In the Wenatchee fruit-growing district of Washington the first irrigation usually is given in April or early in May. Then follow three or four waterings at intervals of 20 to 30 days. At Montrose, Colo., water is used three to five times in a season. At Payette, Idaho, the same number of irrigations is applied, beginning about June 1 in ordinary seasons, with repetitions at 30-day intervals. As a rule, the orchards at Lewiston, Idaho, are watered three times, beginning about June 15. At Boulder, Colo., from two to four waterings suffice for fruit trees, the last being given on or before September 5, so that the new wood may have a chance to mature before heavy freezes occur. In the Bitterroot Valley, Mont., young trees are irrigated earlier and oftener than mature trees. Trees in bearing are, as a rule, irrigated about July 15, August 10, and August 20 of each year.

Utah orchards are rarely irrigated before June 15 in the central part of the State and before July 1 in the northern part. Water deliveries to porous bench lands occur, as a rule, every eight days, and every two weeks on the heavier types of soil.

In studying the soil and climate in connection with the frequency of irrigation of the citrus belt of southern

California, Valle<sup>10</sup> concluded that an interval between irrigations of five weeks brought about the highest fruit yields in the coastal territory, that three weeks was best for the foothill territory, and that four weeks was best for the intermediate territory. The time and number of irrigations for the deciduous orchards of Santa Clara Valley, Calif., are usually a first watering for prune trees of 4 to 5 acre-inches late in May or early in June, and a later watering of 5 to 6 acre-inches. Cherry, peach, and apricot trees are given their first irrigation earlier, with a shorter interval between the first and second irrigation. Pears receive from three to five irrigations.

In Yakima Valley, Wash., the irrigation season for orchards extends from about April 15 to September 15. This being a locality of light precipitation, the number of irrigations runs from 5 to 10 and averages over 7 in the season.

### REMOVAL OF EXCESS WATER

Loss of water is not the only result of deep percolation. The water which escapes in this and other ways usually moves through the soil slowly until it reaches some underground body of water at a lower level. In case orchards have been planted at these lower levels the rise of the ground water should be watched carefully. An ordinary small posthole auger is one of the most convenient tools to use in making test wells to disclose the behavior of the ground water. Injury to the trees or their destruction may be caused by submergence of the roots, the accumulation of mineral salts or alkali at or near the surface, or by both. Artificial drainage must be provided in time to prevent this.

Open drains in orchards occupy valuable land, obstruct field work, and are expensive to maintain. Some of these objections may be minimized if the drains can be located along the lower boundary of the tract, otherwise covered drains are preferable. Fruit-tree roots, with the possible exception of those of pear trees, are not likely to give trouble in clogging drains. Willows, poplars, and cottonwood trees should not be permitted to grow near underdrains. Under ordinary conditions where the soil is stable the cost of drainage will vary from \$15 to

<sup>10</sup> VALLE, ROLAND S. A SURVEY OF ORCHARD PRACTICES IN THE CITRUS INDUSTRY OF SOUTHERN CALIFORNIA. P. 23. Univ. of Calif. Coll. of Agr., Agr. Expt. Sta. Bul. 374.

\$40 per acre. Where a narrow strip in the bottom of a draw is to be protected or where unstable soil exists the cost per acre may be considerably higher.<sup>11</sup>

The matter of providing adequate surface drainage is also important. Fruit trees standing in low spots which are almost continuously wet because of neglect of this matter are in grave danger of being killed, even though the ground-water table may be many feet below the surface.

### WINTER IRRIGATION OF ORCHARDS

When water is used outside of the regular irrigation period or, what is in many cases equivalent, outside of the growing season, the practice is termed "winter irrigation." In the Pacific Coast States and Arizona the precipitation usually occurs in winter in the form of rain, and large quantities of creek water are then available. This water is spread over the orchards in January, February, and March, when deciduous trees are dormant. The most favorable conditions for this practice are a mild winter climate; a deep, retentive soil that will hold part of the water applied; deep-rooted trees; and a soil moist from frequent rains. In colder climates, orchards are frequently irrigated after the trees are dormant, so that the moist condition of the soil during the cold months may help prevent winterkilling. Trees are also irrigated early in the spring where the summer water supply is short, to store water in the soil for later use by the trees.

The following examples will suffice to prove the harmful effects of allowing orchards to enter the winter in a dry condition:

About 1,200 acres were planted to peach trees in 1907 in the Green River district of Utah. These made fairly good growth until the winter of 1908-10, notwithstanding the fact that the heavy soil absorbed water slowly. As a result of the washing out of the dam across Green River on July 20, 1909, no water was available after that date for any of the tracts, with three exceptions. Water wheels provided water for two of these, and part of a third was flooded from the canal late in August by waste water produced by a rain storm. All trees except those in the three watered

tracts were winterkilled. The impaired vigor of the trees resulting from the early shutting off of the water, the dryness of the soil, and the severe cold of the following winter, seemed to be the main causes of their destruction.

In 1924 a shortage of water in the peach and cherry tree orchards of Box Elder County, Utah, impaired the growth of many trees. This shortage, coupled with the dryness of the soil, led to much winterkilling. Orchards with cover crops of clover or alfalfa, supplied with sufficient moisture for a healthy tree growth, escaped injury.

In many of the orchards of Montana no water is applied in summer irrigation after August 20; but, because of the prevalence of warm chinook winds which not only melt the snow in a night, but rob the exposed soil of much of its moisture, one or two irrigations are frequently necessary in midwinter.

To prevent the winter injury to orchards in Colorado the following method is used.<sup>12</sup>

As soon as the fruit has attained full size, irrigation should cease and the land be permitted to dry. Later, after the trees have shed their leaves and become dormant, the orchard should be thoroughly irrigated, usually late in October or the fore part of November. This irrigation will fill the soil and the trees with moisture and prevent them from drying out during the winter. In most cases the winterkilling is not due to low temperature, but to the dry, cold air which takes the moisture out of the trees when they are unable to recoup their supply from the dry soil.

The immature top shoots of young walnut trees are frequently injured in winter and die suddenly in the early spring. The injury, according to Batchelor and Reed,<sup>13</sup> in most cases is caused by frosts, sunburning, winter drought, a high water table or alkali, or combinations of these conditions. A preventive measure against frost injury is to use water sparingly or not at all in late summer, in order to hasten the maturing of new growth. The only remedy for winter drought is to apply sufficient water during the dormant season to provide amply for transpiration; and the lowering of the water table by drainage is the usual remedy for saturated soil in the root zone.

<sup>11</sup> Farm-drainage problems are discussed at length in U. S. Dept. Agr. Farmers' Bul. 805. The Drainage of Irrigated Farms, and in U. S. Dept. Agr. Bul. 190, The Drainage of Irrigated Land, both by R. A. Hart.

<sup>12</sup> SANDSTEN, E. P. ORCHARD MANAGEMENT. Colo. Sta. Bul. 250.

<sup>13</sup> BATCHELOR, L. D., and REED, H. S. WINTER INJURY OR DIE-BACK OF THE WALNUT. Univ. of Calif. Coll. of Agr., Agr. Exp. Sta. Cir. 216.

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February 16, 1927

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<i>Bureau of Public Roads</i> .....	THOMAS H. MACDONALD, <i>Chief</i> .
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